Section 5 Human Intrusion[1]

Comment Issues Page #

Issue A: The human intrusion scenario analysis is an implementation detail that should be left up to DOE and NRC to deal with and should not be included in the EPA standard.

1. Specifying potential scenarios for human intrusion is an implementation issue that falls completely within NRC's authority. (230, 237)

2. EPA feels that the human intrusion standard is inconsistent and unnecessary. If however it is decided such a standard is necessary in view of the NAS recommendations it should be made qualitative and the fixed location could be made less prescriptive by proposing any drill site above the repository footprint or leaving that implementing detail to NRC. (558)

3. Prescription of the stylized calculation for evaluating human intrusion should not be part of EPA standards. Specification of the stylized calculation more appropriately belongs in the NRC's implementing regulations. (311, 604)

4. Specification of a calculation for NRC to use to evaluate the consequences of human intrusion on repository performance is a matter of implementation to be determined by NRC. NRC has proposed implementing regulations at 10 CFR part 63, that include a proposal for evaluating the consequences of an assumed intrusion, on which we have received significant comment. We will fully consider these comments prior to finalizing the rule. The EPA should eliminate the separate provisions for evaluating human intrusion by deleting §§197.25 and 197.26. (617)

5. EPA recommends that the standard for human intrusion should be part of this rulemaking, but the implementation should not. Human intrusion scenarios are a matter of implementation of and compliance with the proposed radiation standard. We consider that potential scenarios definitions fall within NRC's mandated authority. (770)

[1] All acronyms are defined in Appendix B.

Response to Issue A:

Comment on this issue expressed opinion that the framing of the human intrusion scenario should be left as an implementation detail for NRC, or that the intrusion scenario standard is unnecessary. EPA disagrees with these comments for the reasons discussed below, and we also believe that framing the basic elements of the stylized intrusion scenario is a necessary part of the standard in order to supply the context for the more detailed implementation effort NRC will perform.

Under the mandate from the EnPA to develop a standard to protect public health, EPA believes that human intrusion is an appropriate component of the standard. There are two means by which radionuclides can be released from the repository: (1) by the expected gradual degradation of the waste containment barriers (the engineered components of the repository, e.g., the metallic waste containers) through natural processes and events and the consequent slow release of radionuclides in the wastes, or (2) by either deliberate or inadvertent disruptions of the waste containment and isolation system. Human intrusion is the prime example of disruption of the repository system with consequent releases of radionuclides to the environment and exposures to the population. Under the EnPA mandate to develop protective health and safety standards, developing a standard for any deep geologic repository requires both avenues for potential radionuclide releases to be considered so that the standard is complete and protective. For these fundamental reasons we believe that human intrusion is an appropriate component of the Yucca Mountain standard. The relative importance of these two release modes can differ depending on the specific geologic setting involved. For example, releases from the gradual degradation of the natural and engineered barriers in a salt repository would be very minor because of the isolation the geologic setting provides from the surrounding ground waters. For this setting, the human intrusion into the repository offers the most important potential for releasing radionuclides to the surrounding environment. Salt formations are also often the host for exploitable resources and, consequently, intrusion has a higher probability than less resource-rich geologic settings. Therefore, performance analyses of human intrusion scenarios play a major role in regulatory decision making. In contrast, a repository site in fractured rocks, through which ground water can more easily access the disposed wastes, would have a higher potential for releases through degradation of the repository containment barriers. For this case the relative importance of human intrusion caused releases would depend on the abundance of exploitable resources in that geologic setting. Although the relative importance of the two release modes will vary, they must both be included to assure a protective approach to developing the standard.

Reflecting the rationale above, there are two basic sources for guidance in developing the site-specific standard for the Yucca Mountain repository: the guidance and recommendations provided in the NAS Yucca Mountain Report, and the generic performance standards contained in 40 CFR part 191. Specific guidance for framing details of the human intrusion scenario appropriate for the Yucca Mountain site is given in the NAS Report. The NAS guidance acknowledged that analyses of human intrusion have value in terms of providing insight into "the degree to which the ability of a repository to protect public health would be degraded by intrusion" (NAS Report, p. 108). The NAS Report provided additional recommendations on the nature of the intrusion scenario it believed appropriate for the Yucca Mountain site; the approach to be taken for

construction of the scenario to be addressed in a consequence analysis; the acceptable level of risk against which the results of the consequence analysis should be judged; and the relation of the human intrusion assessments to the expected case assessments for repository performance used to judge compliance with an individual protection standard (NAS Report, Chapter 4). In addition, NAS recommended, "Because the form and frequency of intrusions cannot be predicted ... To provide for the broadest consideration of what scenarios might be most appropriate, we recommend that EPA make this determination in its rulemaking to adopt a standard" (NAS Report, p. 111). From the extensive recommendations in the NAS Report, it considered the assessment of human intrusion to be an appropriate component of the Yucca Mountain standard, and we agree with its assessment.

Moreover, as explained in Section I of the preamble to the final rule, 40 CFR part 191 contains the generic standards appropriate for any deep geologic repositories used for disposal of SNF, HLW, or TRU radioactive waste. Without a sound site-specific rationale for omitting a component of the 40 CFR part 191 standard, the major components of the 40 CFR part 191 standard (i.e., individual protection, and ground- water protection, containment standard and assessment of human intrusion) may serve as starting points for the development of any site-specific standard. Human intrusion is included in 40 CFR part 191 as a component of the standard.

In summary, the inclusion of human intrusion into the Yucca Mountain standard is appropriate from very fundamental principles, i.e., the intrusion is a way in which exposures to the population can occur and therefore has potential health consequences. NAS, in its recommendations to EPA, supported the inclusion of human intrusion analyses in the standard and the development of intrusion scenarios for consideration in the EPA rulemaking process. In addition, human intrusion has been established as a generic component of repository regulation, i.e., it is included in the generic standards (40 CFR part 191) established by law and intended for any and all repositories for the type of waste intended for the Yucca Mountain repository. We therefore disagree that the provisions in the rule addressing human intrusion should be removed from the standard (comments 237, 558, 617).

A number of comments offered opinion that human intrusion scenarios and assessments should be considered as implementation issues and left to the discretion of NRC as the implementing authority (comments 230, 558, 604, 617, 770).

For the reasons described above, EPA believes that human intrusion assessments should be a fundamental part of the health and safety standards for the Yucca Mountain site, and as such we believe the analysis of human intrusion scenario consequences should not be left to the discretion of the implementing agency to include or omit from the licensing process. In fact, NAS explicitly stated, "EPA should specify in its standard a typical intrusion scenario to be analyzed for its consequences on the performance of the repository" (NAS Report, p. 108). We agree with this position and we believe that specifying the general components of the intrusion scenario is necessary to assure that it is assessed appropriately during implementation. As explained below,

we also believe we have left sufficient flexibility for NRC to more fully define the intrusion scenario so that actual consequence analyses can be performed.

The NAS also made other more specific recommendations about the approach and requirements for the treatment of human intrusion in the EPA standard, with which we agree and have incorporated into the standard. The NAS recommended, among other details, that:

> (1) "EPA should specify in its standard a typical intrusion scenario to be analyzed" (NAS Report, p. 108) - and we have defined a stylized drilling intrusion scenario (Section 197.26) consistent with other NAS recommendations (NAS Report, Chapter 4);
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> (2) "Because the assumed intrusion is arbitrary ... the analysis should not be integrated into an assessment of repository performance ..... but rather should be considered separately" (NAS Report, p.109) - we have separated the individual protection and human intrusion standards (Section 197.25);
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> (3) "EPA should require that the conditional risk as a result of the assumed intrusion scenario should be no greater than the risk levels .... acceptable for the undisturbed repository case" (NAS Report, p. 113) - we apply the same exposure limits to both the individual protection and human intrusion standards (Section 197.25).

EPA believes that specifying the most basic aspects of the human intrusion scenario to be assessed, and the standard against which the results of the consequence analysis must be judged, are necessary in order to supply the context for the more detailed implementation that NRC will perform as part of its licensing functions. We note that the NAS comments conclude that, "..the proposed EPA approach to human intrusion appears to have followed the TYMS recommendations very closely" (Docket A-95-12, Item IV-D-31). We have specified sufficient details concerning the stylized intrusion to assure it is assessed as we (and the NAS recommendations) intended, but we have left considerable flexibility to NRC in further defining the details of the assessment. In fact, our requirements for the stylized intrusion scenario are limited, so additional details must be specified before any actual consequence calculations could be performed, leaving considerable flexibility to both DOE and NRC for implementation issues. For example, although we have specified that the intrusion breaches a waste package and establishes a connection with the saturated zone below the repository [consistent with NAS recommendations (NAS Report, p. 111)], we have not specified the mechanism(s) by which radionuclides would migrate from the waste package, through the poorly sealed borehole and along the ground-water travel path. These potential variations allow NRC to exercise considerable flexibility in implementing the standard. In addition, our standard does not preclude NRC from requiring analyses of additional intrusion scenarios if, in its judgement, such scenarios are important for compliance purposes. We note that the NRC comments (comments 604, 617) about this implementation issue did not support its position that specifying an intrusion scenario and a consequence calculation for compliance purposes is an inappropriate action for the EPA rulemaking, other than to say that an intrusion scenario had been incorporated into its draft standard for the Yucca Mountain repository. As explained above, we believe that human

intrusion analyses are appropriate for the standards, we have specified sufficient detail to assure the stylized intrusion scenario is assessed as we (and NAS) believe is appropriate. We have, however, left sufficient room for NRC to exercise its discretion on implementation. We believe that our standard sets the context in which the intrusion assessment analyses and decision making should be implemented. Additional discussion on implementation details is presented in the responses to comments (grouped under Issue D below) dealing with our framing of the intrusion scenario.

One comment suggested that the intrusion scenario be treated qualitatively and the scenario be modified to leave placement of the drill hole as an implementation detail (comment 558). As noted above, the NAS recommendations about the level of risk from the intrusion releases unquestionably implies a quantitative assessment of potential release consequences, rather than a simple "qualitative" assessment. The NAS also explicitly stated a measure for the repository "resilience" assessment, "EPA should require that the conditional risk as a result of the assumed intrusion scenario should be no greater than the risk levels ... acceptable for the undisturbed repository case" (NAS Report, p. 113). EPA believes that only a quantitative calculation, and a comparison against a set limit, allows the intrusion analysis to be evaluated as intended by NAS and EPA. We are not aware of any "qualitative" approach that would allow the consequences of an intrusion to be definitively judged in a licensing process. Unless the results of the consequence analyses are compared against a set limit, their use in compliance determinations is ambiguous, particularly if a wide range of speculative scenarios (with equally speculative and varied dose estimates) are assessed, any one of which is no more defensible than any other in terms of the probability of their occurrence.

On the question of leaving the placement of the intruding drill hole as an implementation detail, the intent of the stylized intrusion scenario is to avoid speculative scenarios while allowing the "resilience" of the repository to be evaluated by an intrusion scenario that would unquestionably result in some level of exposure. By requiring that the waste package be penetrated and a connection established with the underlying ground-water flow system, a pathway leading to some level of exposure is assured and an analysis is possible. If the borehole placement was left undefined, other drill hole placements that would not directly penetrate the waste packages are possible, and the release pathways and mechanisms involved would be highly speculative, making their use in regulatory decision making ambiguous. For a drilling intrusion that does not penetrate a waste package, a case can be made that no releases and consequently no doses to the public would occur. By having intrusion scenarios that vary between some level of exposures to none at all, the decision making process becomes dependent on judgements between speculative assumptions of competing scenarios, resulting in an extremely difficult decision making process and limiting the potential for consensus between the parties involved. In our opinion, the NAS recommendations are intended to avoid such a situation by proposing a limited "worst-case" type of stylized scenario where releases are possible and then examining this single scenario against the expected undisturbed repository case as the test of resilience against a fixed marker for performance. For these reasons, we believe the placement of the drill hole can be an implementation detail; however, it must be assumed that it penetrates the waste package and establishes the connection to the saturated zone.

Issue B: The human intrusion analysis should be used as a test of repository resilience only and not as a standard with a specific dose limit in the EPA rulemaking.

1. The proposed intruder scenario is incredible and no performance standard for it should be established. The intruder scenario should be evaluated only to assess the repository's resilience. (218, 573)

2. The alternatives proffered in proposed 40 CFR § 197.25 do not clearly limit the analysis of human intrusion to an RMEI dose arriving through the pathway created by the presumed human intrusion. The requirement in both alternatives to consider "all potential environmental pathways of radionuclide transport and exposure," unnecessarily confuses the purpose of the human intrusion analysis with the overall system performance assessment and should be deleted. (278)

3. The NAS findings and recommendations make clear that any human intrusion analysis should be separate from the calculation of compliance with the risk limit and should be limited to a measure of the consequences to the general public of such a highly improbable event. The EPA acknowledges and purports to concur with this recommendation in its discussion of the proposed rule and should conform the text of the final rule to this principle. (279)

4. It appears that EPA has interpreted the NAS' guidance as drilling into a failed canister sometime in the far future and still meeting the individual dose limit for an unpenetrated canister system. This then becomes a limiting design requirement for the repository as interpreted by EPA. We believe that it is instructive to understand the consequences of such a stylized scenario, but using it as a design requirement does not make sense. Thus, setting a dose limit is unnecessary for such an intrusion. (321)

5. A postulated human intrusion (e.g., a bore-hole through a canister and continuing into the saturate zone) would be an important way to analyze the resilience of the disposal system. (345)

6. The single-borehole scenario seems to be a reasonable basis to judge the repository's resilience to human intrusion. (467)

7. Drilling for water, although an important resource for the region, is not likely to occur above the repository, as opposed to nearby dry washes, where the depth to ground water is significantly less. ...The results of the human intrusion analysis should be considered only as a qualitative indicator of resilience of the repository, rather than be compared to a finite limit. If Alternative 1 in the rule is not changed to eliminate any comparison to [a] finite limit, DOE believes that Alternative 2 should be selected for the final rule. (644)

8. This circumstance seems inconsistent with §197.15, which states that DOE must assume that human knowledge will remain constant. With present day knowledge of the occurrence of ground-water resources, no reasonable party would explore for ground water in the area of the Yucca Mountain repository, because the terrain is too rugged for either agriculture or community use, . . (558)

9. We find it far-fetched to imagine a scenario in which drillers would seek to drill vertically on the slopes of Yucca Mountain through the repository field, happen to strike a decomposed waste package, withdraw the drill with radioactive contamination and not realize they have contacted the radioactive material. If drillers are drilling for water, why would they choose to start their drilling at a greater vertical distance from the likely water table in the nearby valleys? (266)

10. [T]he proposed EPA approach to human intrusion appears to have followed the TYMS recommendations very closely. (399)

Response to Issue B:

EPA believes it is appropriate to closely follow the recommendations of NAS on human intrusion, as explained in more detail below and in Issue A above. The text below discusses comments we received on the framing of the intrusion scenario as a test of repository resilience.

Some comments stated that a single borehole penetration is a reasonable test and preserves the NAS intent that human intrusion be kept separate from, and not confused with, the individual protection standard and used as a test of the repository's resilience to an inadvertent intrusion (comments 345, 467). EPA agrees with these comments, particularly in consideration of the NAS recommendations, which we have followed closely in framing the standard. We believe, as NAS pointed out, that it is not possible to scientifically defend an assertion that human intrusion can be unequivocally eliminated by any system of institutional controls, and that there is no scientific basis for "estimating the probability of inadvertent, willful, or malicious human action" (NAS Report, p. 107). The NAS recommendations clearly mean that institutional controls in themselves cannot preclude the possibility of human intrusion into the repository. As explained in the responses under Issue A, human intrusion is a means through which the repository containment function can be disrupted with resultant exposures to the public and therefore should be considered in setting standards to protect public health. Since the potential for intrusion cannot be completely eliminated, we believe it is a prudent and protective approach in the Yucca Mountain standard to assume such an intrusion occurs, since exposures are possible from an intrusion.

Some comments stated that the proposed intrusion scenario at Yucca Mountain is not credible (i.e., drilling for water at the crest of Yucca Mountain rather than in the adjacent valleys), and should only be evaluated to assess the repository's resilience (comments 218, 266, 558, 573, 644). Relative to these points, the NAS recommendations were exhaustive in pointing out that predictions about human activities, states of technology, effectiveness of institutional controls, etc., are not amenable to scientific analyses and justification (NAS Report, Chapter 4). While the attractiveness of drilling for water resources over the reference repository layout is small and an actual intrusion is improbable, it cannot be completely eliminated, as NAS pointed out. The NAS concluded it would not be scientifically defensible to develop arguments about the probability of inadvertent human intrusion or to drive the requirements with the aim of preventing such intrusions. Rather, NAS recommended that an inadvertent intrusion be assumed to occur, regardless of arguments about the relative probabilities of different intrusion scenarios, that the intrusion be assumed to connect a breached waste package to the underlying ground water, and

that the consequences be evaluated in the same manner used to evaluate the individual protection standard. NAS further qualified the situation by eliminating consideration of the effects of radioactive materials brought to the surface by the intruder or their dispersal into the environment. The intent was simply to evaluate the expected repository performance in a stylized way through a limited by-passing of the engineered barrier system as a test of the repository's resilience to such a disturbance. In this way, the issue of intrusion probability is not raised, but rather, the more important concern over potential consequences is addressed directly. The point of the intrusion scenario is to test the repository system for a limited containment breach scenario, not to make probability assessments about a wide range of hypothetical intrusion scenarios and their resulting dose assessments. The stylized framing of the scenario and the performance measure applied are intended for the resiliency test alone. Low probability arguments about the actual potential for an intrusion serve as additional supporting information lending increased confidence that excessive doses to the population are unlikely if the repository passes the "resiliency test" from effects of a limited "worst-case" type of hypothetical intrusion event. We do not believe, in the light of the NAS conclusions, that low-occurrence probability arguments are sufficient justification for deleting human intrusion considerations from the standard. We have treated the intrusion assessment as a "resilience" test for the repository; however; we believe a quantitative standard (the exposure limit) is necessary to assess the results meaningfully in regulatory decision making and therefore a performance standard is needed and appropriate.

Another comment specifically stated that the intrusion scenario should not become a limiting design requirement (comment 321). EPA is not requiring that the repository design be developed to minimize the potential for human intrusion, again following the intent of the NAS recommendations to avoid driving requirements or design by speculative assumptions. As a simple test of repository resilience, the intrusion scenario as defined in the standard (Sections 197.25 and 26) would apply no matter what specific design is used, and we believe NAS considered it in this light (NAS Report, pp. 111-112). The stylized scenario assumes a waste package is penetrated rather than requiring any specific design measures to prevent or minimize the possibility of such a penetration, which would be the form of the standard if it were to function as a design constraint. In fact, the repository design already contains features that in reality argue against a high probability of penetrating a waste container during routine drilling for water (the only currently known resource in the repository area). The use of thick-walled waste packages would tend to deflect drill bits in the open waste emplacement drifts, as would the use of drip shields in the current design (see the BID, Chapter 8). We consider it a sufficient test of repository resilience to assume an intrusion occurs and evaluate the consequences using the same analytical assumptions and methods used to assess releases and transport of radionuclides under the expected performance case. In this sense also, we believe that the stylized intrusion scenario in no way imposes design constraints on the repository, because a penetration of the waste package is assumed to occur (regardless of the waste package design) and the rest of the engineered barrier is by-passed by assuming a connection is made from the breached waste package to the underlying saturated zone. We also believe the specifics we have defined for the drilling intrusion also limit the range of possible stylized intrusion analyses that could be envisioned in their absence, and therefore pose no constraints on repository design to address an otherwise large number of possibilities for drilling scenarios.

One comment stated that the requirement to consider "all potential environmental pathways of radionuclide transport and exposure" (Section 197.25), unnecessarily confuses the human intrusion assessment with the performance assessment used to address the individual protection standard (comment 278). EPA incorporated that phrasing to be consistent with phrasing used for the individual protection standard (Section 197.20), and also to follow the NAS recommendation that the consequences of the intrusion should be assessed in the same manner as the expected case repository performance relative to the individual protection standard (NAS Report, p. 112). We recognize that under the range of expected conditions the ground-water pathway is the important pathway for potential doses, and we have framed the standard to require analyses through this pathway. We anticipate that the container penetration scenario will not be inappropriately biased to other pathways not similarly treated in the individual protection compliance assessments. The potential for such a bias could come during implementation of the standard, but we believe that we have given sufficient direction in setting the basic framework for the stylized scenario (establishing a connection from a breached waste package to the underlying saturated zone below the repository) that it is clear the ground-water pathway is the focus of the analyses. Section 197.26 (e) clearly limits the analyses to those radionuclides released from the breached waste package and transported to the saturated zone, thereby eliminating pathways other than through the ground water. We also believe the NAS description of the intent of the intrusion scenario is clear – that the analyses is to be a test of the resilience of the repository system under expected conditions and not as an assessment for the creation of new pathways not included in the assessment of anticipated repository performance. More specifically, as an example, NAS recommended that hazards from bringing radioactive materials to the surface during a drilling event should not be considered (NAS Report, pp. 114-115), but rather that the analysis should focus on "modification of the repository's barriers and the consequences of these modifications for the ability of the repository to perform its intended function" (NAS Report, p.115). Thus, EPA believes that the concerns of both comments 278 and 279 are adequately addressed.

Two comments stated that the human intrusion analyses should not be compared against a specific limit, but rather be a qualitative measure only (comments 558, 644). EPA has followed the NAS recommendations in separating the analyses from the expected performance case and in this way we have assured that the results do not obscure or confuse the issue of the expected performance of the repository system. However, NAS also recommended that the standard require a consequence analysis for the intrusion scenario (NAS Report, p. 111), and that the "risk as a result of the assumed intrusion should be no greater than the risk levels that would be acceptable for the undisturbed repository case" (NAS Report, p. 113). We agree with these recommendations, which imply that projected releases would have to be compared against the same fixed limits imposed for the undisturbed performance case. We have therefore specified that doses to the receptor during the regulatory time frame must be compared against the same level as that used for the undisturbed performance. We believe that to be meaningful, a test of repository "resilience" would have to involve a comparison of potential doses from the intrusion scenario against the same fixed limit applied to the expected performance case. Otherwise no conclusive judgement could be made that the repository is in fact resilient to the intrusion.

Comment 558 also suggests that the location of the intrusion penetration be either left to NRC or allowed to be anywhere over the repository. This proposal is discussed under Issue A above. The exact placement of the drill hole can have an effect on the calculated doses by allowing some additional travel distance for radionuclides released to the saturated zone. However, we consider this an implementation detail that should be left to DOE and NRC to determine in their efforts to evaluate uncertainties in these and other performance assessments; ultimately measuring compliance with the standard.

Issue C: Has the framing of the human intrusion standard reasonably addressed the time frame, probability and consequence implications of an intrusion?

1. The DOE should assume a penetration and assess the consequences. (82, 311)

2. It is extremely likely that the EPA scenario will occur, as there will be drilling during exploration for resources or intentional drilling in pursuit of the SF and HLW. (169)

3. ICRP has no special opinion on the scenario proposed by EPA. What [is] missing in the EPA proposal is rather a consideration of specific associated radiological criteria to be complied with, as human intrusion means both that there is no scientific basis for predicting the likelihood of such an event and by definition an intrusion has bypassed all the barriers. (516)

4. The same individual protection standard should apply in the case of human intrusion as for an undisturbed repository, and so of course support the EPA proposal to apply the same 15 mrem limit here. (311)

5. I[t] has always seemed futile to argue about the probability of human intrusion into the repository. A much more reasonable and conservative approach is to assume that an intrusion would take place, within the regulatory period, and to assess its consequences. (305)

6. It is unclear if the HI assessment considers or excludes unlikely or very unlikely natural events from consideration when compared to the individual protection standard. EPA should clarify whether the standard includes or excludes such events. (650)

Response to Issue C:

As discussed in Issue A, human intrusion is one way releases from the repository can occur, and consequently it is an appropriate component of the standard. The NAS recommendations also considered human intrusion to be an appropriate part of a standard for the Yucca Mountain site as explained previously in Issues A and B. EPA agrees with the NAS recommendations and has followed them closely in framing the intrusion scenario in the standard.

A common focus of a number of comments is the assumed probability of the intrusion (82, 169, 305). Some comments state that intrusion is likely (169), or that an intrusion should be assumed (82), or more specifically that it should be assumed to occur within the regulatory period (305).

A fundamental question in evaluating an intrusion scenario for any repository situation is determining the nature of the intrusion and the probability it will occur. These aspects were critically examined by NAS in its recommendations to EPA for developing the Yucca Mountain standard.

Comment 169 suggests that a drilling intrusion is likely due to resource exploration or intentional drilling in pursuit of the repository contents. While other comments disagree relative to the probability of drilling intrusions at Yucca Mountain (see comments under Issues B and D), EPA has assumed that an intrusion occurs (see earlier discussions in previous issues for the rationale for this assumption) and should be treated in a stylistic way to test the performance of the repository system to a limited by-passing of the engineered barrier system, as NAS recommended (NAS Report, Chapter 4). In this sense we agree with the intent of the comments, i.e., that the intrusion should be assumed. We have identified the nature of the drilling (water well drilling, Section 197.26) so that the size of the penetration is fixed to reduce the unnecessary arbitrary assumptions about this characteristics of the stylized scenario, as NAS suggested (NAS Report, p. 111). This comment also proposes that deliberate intrusion into the repository is possible. The NAS considered this possibility and concluded (NAS Report, p. 114) it is unproductive to attempt to determine means to protect against risks from deliberate actions, i.e., if there is a deliberate attempt to intrude no design measures could assure the intrusion could not occur. We agree in this assessment and we assume that the drillers would be aware of the risks and potential consequences of such intrusions. We believe that assessing the effect of deliberate intrusions would be fundamentally different than the repository "resilience test" NAS recommended (and we have adopted), and the analyses would supply no useful information about the repository's performance. If a deliberate intrusion were to occur to tap the repository contents, there would not be a connection established between the repository level and the underlying ground-water system. Releases would be from repository wastes brought to the surface during drilling (or subsequently excavated) and the pathways for human exposure would be completely different than the stylized drilling intrusion proposed. The consequences of such an intrusion analysis would not be a test of the repository resilience relative to the expected undisturbed performance case and therefore offer no measure of the repository's "resilience", as the NAS recommendations emphasize (NAS Report, pp. 114-115). We have therefore not included consideration of deliberate intrusion as a component of the standard.

The question of when the intrusion occurs is important for defining the parameters of the intrusion performance assessment. Comment 305 suggests that the intrusion should be assumed to take place sometime during the regulatory period (10,000 years), while other comments imply no set time period (comments 82, 169). The text below explains the approach EPA has used to set the time for the intrusion.

The time frame for the intrusion is simply a means to determine the radionuclide source term appropriate for the analyses after the penetration occurs. Intrusion very shortly after repository closure would make a very different waste inventory available for possible transport from the repository than an intrusion taking place thousands of years after the repository is closed. However, it is not certain whether an early intrusion would necessarily result in significantly higher doses than one later in time, since short half-life radionuclides would undergo significant decay during transport through the ground-water system. If ground-water travel times from beneath the repository to the location of the RMEI were long enough, the short half-life waste inventory could be reduced sufficiently that effectively the same dose could result as for intrusion releases at much later times.

The NAS concluded that "it is not possible to make supportable predictions of the probability that a repository's engineered or geologic barriers will be breached as a result of human intrusion over a period of 10,000 years" (NAS Report, p. 11). With respect to the timing of the intrusion, NAS recommended, "we believe it is useful to assume that the intrusion occurs during a period when some of the canisters will have failed..." (NAS Report, p. 112). As a test of repository performance, this recommendation is consistent with the idea that intrusion be tied at least in some way to the specific features of the repository. EPA believes linking the time frame to actual performance expectations for the repository is more reasonable than fixing the time frame arbitrarily. In this case the connection is with the projected service lifetime of the waste packages. As the waste containers are gradually degraded over time by expected processes in the repository, unnoticed penetration by the current water-well drilling technology we specified (Section 197.26) increases. When some of the waste containers have degraded sufficiently to fail and begin releasing radionuclides, we believe the potential for unnoticed penetration is reasonable. While the containers are fully intact, the potential for current drilling technology to penetrate these containers is less likely since the drill bits can be deflected by the waste package (BID, Chapter 8). Because DOE will have to project waste package containment lifetimes for the expected case performance assessment, the time when waste containers begin to fail will be easily identified and the time for the intrusion easily determined. In turn, this time sets the waste inventory and the source term needed for the intrusion assessment. Whether this time is during the first 10,000 years or beyond is then a site-specific function of the repository, and is compatible with the concept of testing the repository system for the consequences of by-passing the engineered barrier system. We have therefore not required that the intrusion must be assumed to occur with the first 10,000 years. If we were to make such a requirement, we would still have to specify a fixed time, or a means of determining a time. Setting a fixed time would be arbitrary and we have tried to avoid arbitrary requirements. We have selected a means of setting the time for the intrusion based on site-specific performance factors, which we believe is a consistent with the intent of the NAS recommendations.

One comment asked for additional clarification on whether the intrusion assessment included unlikely or very unlikely natural events (650). In Section 197.26 of the standard, EPA states that releases from unlikely natural processes and events are not to be included in the assessments. Very unlikely events would also be excluded from the assessments. See also Section 7 of this document for more discussion of low-probability features, events, and processes.

Comment 311 supported EPA's use of the 15 mrem/yr CEDE exposure limit for the human intrusion standard, consistent with the limit we applied for the individual protection standard. Our choice is consistent with the NAS recommendations on this subject (NAS Report, p. 113). We believe that the same limit set for the individual protection standard should be applied in the case of intrusion releases so that the health-based foundation of the standard is not used inconsistently for the two basic ways releases from the repository can occur – by the gradual degradation of the system or by deliberate disruption of the system. Comment 516 asked that we specify a measure of significance for the intrusion scenario and radiologic criteria for compliance. By setting a standard for exposure limits from the intrusion scenario we have set the radiological compliance criteria requested by the comment. During the licensing process, the implementing authority will review DOE's assessments of the human intrusion exposure scenario, including the uncertainties in these assessments, and make a decision on the compliance question. The measures used to assess the quality and acceptability of DOE's intrusion assessments is an implementation question that must be addressed by NRC.

Comment 516 stated that EPA did not establish a radiologic criteria for protection. The health based exposure limit we have established (15 mrem/yr CEDE) is the radiological criterion against which the performance of the repository will be judged in the licensing process relative to the human intrusion standard.

Comment 516 also suggested that a radiologic performance criteria be used to indicate when intervention is justifiable. The decision to take actions to alter the repository after the wastes are emplaced and the repository is closed would presumably be based on information gathered by some type of monitoring program – an active institutional control. Institutional controls (both active and passive) are assurance measures which EPA has left to the discretion of NRC. EPA does not believe that establishing such measures are appropriately a part of this standard, but are more aptly considered as potential implementation measures for the licensing process. The time period over which active monitoring can be assumed to be effective is a subjective decision based at least in part on judgements about the inherent uncertainties in projecting repository performance. If after consideration of the uncertainties in the DOE assessments of repository performance, NRC feels that a period of active monitoring is necessary, then it would be incumbent on NRC to develop measures that would trigger intervention efforts.

Issue D: EPA should reconsider the assumptions in its human intrusion scenario.

1. More than one intrusion (borehole) should be assumed, as is likely over long time periods (8). One borehole would not adequately discover the geologic variability of the mountain and is therefore unreliable. (371) Future exploration activities would probably result in more boreholes than anticipated in the standard. (371, 502) A more reasonable scenario would be a borehole intercepting a waste package about every 100 years for a period of the first 1,000 years after loss of institutional controls. Our proposed intrusion scenario is sensitive to both the short (up to 1,000 year) and long-term performance requirements of the repository (387b). The possibility of multiple intrusions and their frequency and locations must be considered. (435)

2. Hazards to the intruders and to the public from material brought to the surface should be considered. (435)

3. Deliberate intrusion (sabotage, etc.) within the pre-closure period, that DOE estimates may last 150 years, may be of greater risk. (267)

4. EPA should specify that the repository should have features that would reduce the likelihood of deliberate intrusion. (296)

5. Technology advances that may be economically viable in the future should be considered, such as laser rock cutting. (297, 338)

6. EPA should not assume, based on current DOE package designs, that a driller would recognize penetration of a waste package within 10K years. (545)

7. If the object of the stylized single-borehole scenario is to test the resilience of the system following human intrusion, the scenario should first assume waste package penetration without regard for the resistance of the container. DOE designs have changed considerably over time and likely will again. (387a)

8. If a relatively thin ceramic waste container were used, would it resist a drill bit the same way as a heavy metallic container? (387c)

9. The standard should be at least consistent with the standard applied to WIPP for disposal of transuranic wastes. (377)

10. Human intrusion should be considered in an analogous way to a pre-closure Category 2 design basis event as treated in 10 CFR part 63 (Section 63.111). In this approach there would be no attempt to assess the likelihood of human intrusion, but rather a straightforward consequence-only analysis that would be compared to a compliance limit more appropriate for deterministic evaluation. (237)

Response to Issue D:

The NAS Report recommended that EPA assume that an inadvertent human intrusion to the Yucca Mountain repository would occur and that EPA should specify an intrusion scenario for DOE and NRC to use to evaluate the "resilience" of the repository. "The key performance issue is whether repository performance would be substantially degraded as a consequence of an inadvertent intrusion" (NAS Report, p. 121). Thus, the resilience test should be an analysis of the robustness of the waste isolation system under expected conditions, rather than an assessment of "off-normal" events intended to be design tests. In accordance with the NAS recommendation, EPA proposed a single-borehole intrusion scenario based upon conditions specific to Yucca Mountain. EPA proposed a stylized intrusion in which a waste canister is penetrated during drilling for water resources below Yucca Mountain.

A number of comments stated that more than one drilling intrusion into the repository should be considered for a variety of reasons (comments 8, 371, 387b, 502, 435). While arguments for multiple penetrations can be made, we believe that the NAS conclusions about the difficulties in scientifically determining intrusion probabilities in a reliable manner are correct (NAS Report, Chapter 4), and that arguments for multiple intrusions are therefore unavoidably speculative in nature. For example, comment 387b suggests that a borehole penetration of the waste package should be assumed every hundred years for the first 1,000 years after disposal so that the analysis would use both the short and long half-life radionuclides. This intrusion frequency is inherently an arbitrary selection and the frequency no more defensible than any other frequency for the first 1,000 or the remaining 9,000 years of the 10,000 year regulatory period. Assessing multiple intrusions also opens up numerous variations for the dose assessment calculations - for the timing of these intrusions and their potential interactions, again requiring arbitrary decisions to be made for analysis of many alternative scenarios. We believe that, to the degree possible, speculation should be avoided in framing performance scenarios so that regulatory compliance decisions can be made without involving arbitrary decisions about speculative scenarios. We have therefore followed the NAS recommendations that a single stylized drilling intrusion be examined for its consequences (NAS Report, p. 111). As mentioned previously, we have specified sufficient information in Section 197.26 of the standard to ensure that the intrusion scenario is implemented as we intend, consistent with the NAS recommendations, but with sufficient flexibility remaining for the implementing authority to more fully define an appropriate site-specific performance scenario (see discussions under Issue A). Exactly how the analysis is performed is an implementation detail that EPA believes should be left to the implementing authority. As an illustration of this implementation perspective, one comment (8) stated that more than one borehole would be necessary to assure that the analyses covered the varying geology at the repository site. The comment refers to variations in the geology beneath the repository and possibly along the projected radionuclide travel path in the saturated zone between the repository and the down-gradient exposed population. We believe that how the radionuclide transport pathway from the breached container to, and within, the saturated zone is modeled in detail is properly left to DOE and NRC to determine in the licensing process, since numerous alternatives are possible for modeling. Deciding between alternatives would require a more thorough data base of site parameters than is currently available or necessary to define the stylized intrusion scenario and the exposure limit which are EPA's responsibility in setting the standard. We believe that the single bore-hole stylized intrusion analysis is an adequate test of repository resilience to an intrusion, consistent with the NAS reasoning and recommendations. If the implementing authority, NRC, determines that additional intrusion scenarios are of value in judging the suitability of the site (for example, the early time frame intrusions proposed in comment 387b), it is free to require additional analyses as part of its implementing authority. We have given direction to a limited extent to ensure an intrusion analysis is performed as we intend by stating in Section 197.26(e) that only releases to the saturated zone are to be assessed, and by requiring (in Section 197.25) that "all potential pathways of radionuclide transport and exposure" must be assessed, wording paralleling the individual-protection standard requirements (Section 197.20) and intended to assure that the same approaches and methods used in modeling the undisturbed case are used for the intrusion case also so that a comparison can be drawn between the two. The NAS recommendations for the analytical approach are consistent with our approach (NAS Report, p. 112). In summary,

assumptions for multiple bore-hole intrusions are inherently speculative in nature and offer no significant advantage over the stylized single bore-hole penetration as a test of repository performance and therefore we have retained the single-bore-hole intrusion framework. As noted, NRC may require additional analyses as it implements the standard.

One comment (435) stated that the hazards from radioactive material brought to the surface during drilling should be evaluated. EPA agrees with the NAS recommendation that the intrusion analysis should be a stylized test of repository resilience, i.e., would the expected performance of the repository be compromised by the intrusion? Since the expected performance does not involve this type of waste exhumation to the surface, it would be inappropriate to include hazards from these materials in an assessment of repository resiliency. The NAS also pointedly recommended (NAS Report, pp. 114-115) that consideration of surface dispersal of exhumed wastes during drilling would not provide useful information about any specific repository site or design and therefore would be of little value, i.e., not an appropriate test of repository resiliency. We agree with this conclusion and have not included such considerations in the stylized drilling intrusion described in the standard.

Comment 267 stated that deliberate intrusion into the repository should be assumed. We believe that such intrusions are not appropriate for consideration of compliance with repository performance standards because these standards are not derived to address deliberate disruptions of the repository containment systems. In terms of testing repository resilience as recommended by NAS, a drilling intrusion through the repository, either deliberate or inadvertent, would be treated in the same way, i.e., releases are assumed to be from the breached waste package to the saturated zone and the transport down gradient modeled in the same fashion as an inadvertent intrusion. If the intrusion into the repository was deliberate during the preclosure period, as suggested by comment 267, the intruder would be aware of the hazards involved and no standard EPA established would have any bearing on the deliberate act, particularly for the example of sabotage mentioned in the comment. The NAS concluded that there is "no scientific basis for estimating the probability of inadvertent, willful, or malicious human action" (NAS Report, p. 107), and we agree with that conclusion. We see no value in attempting to develop exposure limits for deliberate acts that willfully expose the participants to radionuclide exposure or are intended as malicious acts. Any standard for exposure limits would also have no meaning or control over deliberate malicious acts. Also, institutional controls (which will include access control - see NRC proposed rule 10 CFR 63.51, 63.121) will be established by the implementing authority for the purpose of preventing disruption of the repository system during the preclosure period and for some time after permanent closure, so the actual potential for deliberate intrusion during the preclosure period should be minimal.

One comment recommended that EPA should specify that the repository have features to reduce the likelihood of deliberate intrusion (comment 296). EPA does not believe that repository design features would be effective in reducing the likelihood of deliberate intrusion. The intruder, being aware of these measures or being determined to proceed with the intrusion, would simply use what ever means necessary to complete the deliberate penetration into the repository. We believe that the institutional controls that will be established for the repository are intended to prevent

deliberate intrusion. Institutional controls, both active controls such as land control measures, and passive controls such as markers, are intended to reduce the potential for inadvertent intrusion. Therefore there will be measures to limit the potential for deliberate intrusion. These measures are referred to as assurance measures and will be included in implementing regulations developed by NRC for the Yucca Mountain site. Institutional controls have no direct link to repository releases and exposure limits which are the focus of the EPA standard, and are more appropriately considered as measures aimed at increasing confidence that the repository system will perform as intended. In addition to the intended function of institutional controls, the repository engineered barriers in the most current DOE design (see the Yucca Mountain Science and Engineering Report, Docket A-95-12, Item V-A-27) will also tend to reduce the actual potential for a drilling intrusion to breach a waste container. The thick-walled metal waste package would tend to deflect drill bits thereby limiting the potential for penetration, as would the titanium drip shields emplaced over the waste packages. In actual instances of drilling intrusions, there is a strong possibility that these materials in the repository would resist penetration of waste packages by water-well drilling and alert drillers that anomalously hard material had been encountered thereby minimizing the actual potential for inadvertent penetration. A related comment asked if thin ceramic waste packages would provide the same level of resistance (comment 387c) as metal waste packages. The answer to this question depends on the nature of ceramic material and cannot be answered in the absence of a specific waste package design, which have not, up to this time, included specifics on ceramic waste package designs. In any event, the resistance of the waste package to drill penetrations serves only to set the time frame for the intrusion so a radionuclide inventory in the breached package can be identified for the assessments. Whether the waste packages are metal or ceramic, DOE will have to determine their longevity in the repository environment for the performance assessments necessary to make release projections for the individual protection standard, and these estimates will serve to set the time frame, and consequently the radionuclide inventory, for the intrusion assessments. We believe the lack of attractive natural resources at Yucca Mountain (Chapter 8 of the BID), the institutional controls that will be imposed through the implementing regulations, and the nature of the engineered barrier system, will provide adequate features to reduce the actual likelihood of actual drilling intrusions.

Other comments (297, 338) stated that technological advancement should be considered in the assessments and that drillers should not be assumed to be able to recognize a waste package penetration occurring within 10,000 years (545). The thrust of these comments is that advances in drilling technology could significantly reduce the potential that drillers would recognize a breaching of the waste packages as it was occurring and stop the intrusion. In agreement with NAS, EPA believes that speculative assumptions should be avoided to the extent possible in framing the standard. Assumptions about advancements in drilling and resource exploration technology in the future cannot be scientifically defended relative to assumptions about what technologies would be available and whether they would be used in resource exploration or exploitation drilling at the site. To avoid unnecessary and unsupportable speculation, we have stated that current drilling practices be assumed for the drilling scenario [Section 197.26 (c)]. With this position, we assume that recognizing the limitations of current drilling technology provides a reasonable bound to establishing the time frame for any possible intrusion, as well as limiting the range of assumptions that would be possible for other details of the release scenarios

analyzed, such as the sizes of the penetration of the waste package and pathway through the unsaturated zone. By framing the scenario in this stylized way, speculative questions about whether a driller would or would not recognize when a waste package penetration occurs are also eliminated, since this particular question relies heavily on the drilling technology used.

One comment (387) stated that the resilience test should assume breaching of the package without regard to the resistance of the waste package to penetration. EPA agrees that the stylized intrusion should assume the waste container is penetrated. The question of whether the waste containers provide resistance to penetration is connected to determining the time frame for the container penetration. As an important (and defining) part of the stylized scenario, the time is important because it determines the radionuclide inventory available in the package for release. The NAS recommended the intrusion be assumed to occur when some of the waste containers have failed but before migration of releases to the ground water (NAS Report, Chapter 4). This recommendation offers a way of estimating an intrusion time frame so that the radionuclide inventory can be estimated. Since the DOE waste packages are designed for long service life times regardless of the specifics of the design and its evolution, the time frame for the stylized intrusion envisioned by NAS is sufficiently long that the short half life portion of the radionuclide inventory will have decayed, leaving only the longer lived component. We agree with the thrust of the NAS recommendation and we have embodied it in Section 197.25 of the standard. By setting the intrusion time as the point where waste containers have degraded sufficiently to allow the penetration to go unnoticed, we have implied that the time should be sufficiently long that the some of the waste packages will have failed or are close to failure.

Comment 377 states that the Yucca Mountain standard should be at least consistent with the standard used for the WIPP transuranic disposal facility. As a matter of policy, this may be appropriate. The EnPA, however, requires EPA to promulgate these public health and safety standards for protection of the public from releases from radioactive materials from Yucca Mountain. Moreover, Sections 8(a) and 8(b) of the WIPP LWA expressly prohibit application of the 40 CFR part 191 radioactive waste disposal regulations, which are applicable to WIPP, to Yucca Mountain. These express statutory mandates require that the Yucca Mountain standard be a site-specific standard specifically applicable to Yucca Mountain. That said, however, EPA believes that the site-specific standard that we promulgate for Yucca Mountain is consistent in approach to that applied for the WIPP facility, with appropriate provisions to address the unique site-specific characteristics of the Yucca Mountain site.

Comment 237 suggests that the human intrusion scenario assessment be considered in a manner analogous to a category 2 design basis accident as treated in the NRC proposed standard 10 CFR part 63. For the reasons we have explained in the previous issues in response to questions about the justification for a human intrusion standard, EPA believes that human intrusion is an appropriate component of the standard. We have also explained that we do not believe it appropriate to treat the human intrusion scenario as a design constraint (see comment 321) as this comment would imply should be the case. For these reasons, we have retained the intrusion scenario as a separate component within the Yucca Mountain standard. The performance objectives from the draft NRC standard referenced in the comment apply to the geologic

operations area during operations until the time of permanent closure. We do not believe that such a short-term consideration of human intrusion is consistent with the approach recommended by NAS. The comment also suggests that the exposure assessment be treated by a deterministic analysis. We have not precluded such an approach to the dose assessment in the language in Sections 197.25 and 26 of the final rule. The choice of performance assessment approaches used by DOE and NRC in the licensing process are implementation concerns, and we have made no requirements about the approach required for the intrusion assessment.

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